Connected Chemistry

Nuclear Unit

Lesson 2: Fission

Student's Lesson at a Glance

Lesson Summary

This lesson has three activities. Students explore how energy is generated at a nuclear power plant through the fission of heavy radioactive isotopes. In the Connecting Activity, students learn about what the process of fission is, the fuels that are commonly used, how much energy is converted during fission, and the products of a nuclear reaction. Following a teacher demonstration of the simulation using uranium-235, students create subatomic sketches, record observations, and answer analysis questions. Students then use the same simulation to explore nuclear reactions of cesium-137. Using the data and subatomic sketches from the simulations, students answer analysis questions.

SWBAT (Student will be able to)

- Define and describe the process of fission
- Describe the flow of energy in a nuclear reaction

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Thermodynamics processes and nuclear reactions are closely related. Looking back on concepts related to thermodynamics may be helpful to understand the concepts in this lesson.
- Nucleus is singular. Nuclei is the plural.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Arrows will be helpful in showing both the direction and velocity in your submicroscopic sketches. In nuclear, you may use zig zag arrows to represent energy. Make sure to define the meaning of arrows in your key.
- You know that the electrons are part of the atomic structure; however, if you were to stand on the edge of the nucleus of an atom and look out you would not be able to see them because of their great distance from the nucleus. This is why electrons are not represented in the simulations.
- There is a periodic table and list of common elements used in the back of this book. You will need to refer to the periodic table often.
- When making subatomic observations, location of the particles in the simulation does not indicate the phase of matter.

Notes

Homework

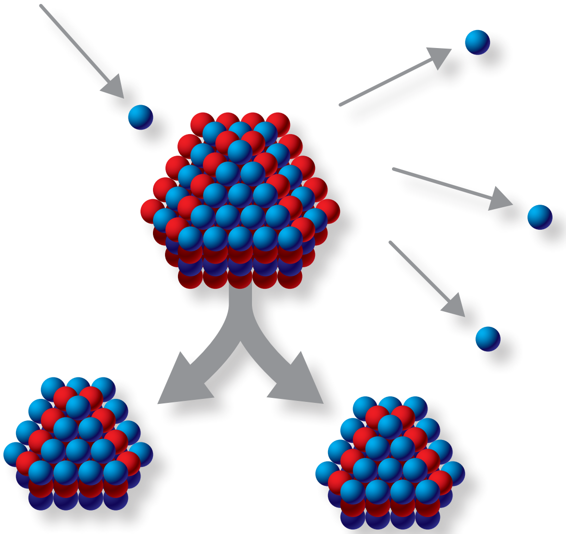
Upcoming Quizzes/ Tests

Activity 1: Connecting

According to the the International Atomic Energy Agency, nuclear power plants across the planet generate 14% of the world's electricity. The United States, Japan, and France account for the largest number of these nuclear power plants. There are 104 licensed plants across the U.S. with the majority of the plants located east of the Mississippi River. These plants produce 19.2% of the country's energy. In contrast, there are over 10,000 fossil fuel plants across the U.S. that produce around 80% the country's energy. How do so few nuclear power plants generate such large amounts of energy? Nuclear power plants rely on **fission reactions** to produce power.

Fission is a nuclear reaction in which the nucleus of a very heavy atom is split into two lighter nuclei, which usually releases three free neutrons and 200 million *electron volts* (eV) of energy. Nuclear power plants use isotopes of the elements cesium, uranium and plutonium as fuel. Uranium-235, cesium-137, and plutonium-239 are used in fission reactions because these isotopes can be split easily into lighter elements. Recall that isotopes have the same number of protons, but the number of neutrons varies, which changes the mass number and the atomic mass of the isotope as shown in the chart below. The difference in the mass number is reflected in the number that follows the name of the element.

Name	Protons	Neutrons	Mass Number	Atomic Mass (amu)
Uranium-238	92	146	238	238.0507
Uranium-235	92	143	235	238.0289
Cesium-133	55	78	133	132.9054
Cesium-137	55	82	137	136.9071



Fission reactions are possible because some isotopes have a large number of protons and neutrons in their *nuclei* with a large amount of potential energy that make them unstable. A fission reaction is initiated by shooting a neutron at high speeds into the nucleus of a radioactive isotope, such as uranium-235. One nucleus of uranium-235 is split into two smaller radioactive nuclei by the collision with the neutron. During the fission reaction, 3.2×10^{-11} joules of energy is released from each atom that is split. Initially this seems like a small amount of energy, but note that this small amount of energy is released when only one atom is split. Remember that one mole of uranium has 6.022 x 10^{23} atoms, so 1 kg of uranium would produce a massive amount of energy if every atom were split during a nuclear reaction. In fact, splitting one kilogram of uranium-235 would produce as much energy as burning 20,000 kg of coal or 11,000 kg of oil.

In addition to energy, three neutrons are usually released during a fission reaction. Of the three free neutrons released, two come from the original nucleus and the other is from a neutron being shot in to initiate the fission reaction. These neutrons move at a high velocity with tremendous kinetic energy and ultimately collide with up to three other uranium-235 nuclei. More neutrons are thus released, causing a chain reaction. In nuclear reactors, this process must be controlled carefully to prevent it from progressing too quickly and releasing too much energy at once. The energy that is given off from the fission reaction is used to heat water to produce steam. The steam is used to turn giant turbines and produce electricity that is carried by power lines to homes and businesses.

1. If a neutron with very low kinetic energy is fired at the uranium-235 nucleus, what do you think will happen when it hits the nucleus? *Support your claim with evidence.*

2. What types of energy are involved to produce electricity from a fission reaction? *Support your claim with evidence.*

3. The process of fission is one type of nuclear reaction. Are nuclear reactions the same as chemical reactions? *Support your claim with evidence.*

4. During fission, a massive uranium-235 nucleus splits into two smaller nuclei. Using the simulation, how would you be able to determine what elements those nuclei are?

Activity 2: Demonstrating Fission

Demonstration: *Use Simulation 2, Set 1*

- *Create an initial sketch of uranium-235. Record your observations and the mass number. Make sure to include a key.*
- *Using the simulation, your teacher will shoot a high speed neutron at the nucleus of uranium-235.*
- *Your teacher will pause the simulation immediately after the nucleus is split. Create a sketch of the two smaller nuclei that were created. Record observations and the mass number of each of the new nuclei.*
- *Your teacher will reset the simulation for a second trial.*
- *For trial 2 you do not need to create an initial and final sketch. Shoot the neutron at the nucleus. Pause the simulation immediately after the nucleus is split.*
- *Create a sketch of the two smaller nuclei that were created. Record observations and the mass number of each new nuclei.*

<table>
<tr><th></th><th>Create a Subatomic Sketch</th><th colspan="5">Record Data from Monitors</th></tr>
<tr><td rowspan="3">Initial</td><td rowspan="3"></td><td colspan="2">Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td colspan="2">Neutrons</td><td></td><td>Atomic Number</td><td></td></tr>
<tr><td colspan="5">Record Your Observations</td></tr>
<tr><td rowspan="5">Trial 1</td><td rowspan="5"></td><td rowspan="2">Element 1</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td>Atomic Number</td><td></td></tr>
<tr><td rowspan="2">Element 2</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td>Atomic Number</td><td></td></tr>
<tr><td colspan="5">Record Your Observations</td></tr>
</table>

<table>
<tr><td></td><td>Create a Subatomic Sketch</td><td colspan="5">Record Data from Monitors</td></tr>
<tr><td rowspan="5">Trial 2</td><td rowspan="5"></td><td rowspan="2">Element 1</td><td>Mass Number</td><td></td><td>Protons</td><td></td></tr>
<tr><td>Neutrons</td><td></td><td>Atomic Number</td><td></td></tr>
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<tr><td>Neutrons</td><td></td><td>Atomic Number</td><td></td></tr>
<tr><td colspan="5">Record Your Observations</td></tr>
<tr><td colspan="7">Key</td></tr>
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5. How many neutrons are released per one nucleus hit?

6. In Trial 1, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

7. Do the two elements that are formed after fission have more or less chemical potential energy than the original uranium-235? *Support your claim with evidence.*

8. In Trial 2, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

9. Were the same elements made in trial 1 and 2? How do you know?

Activity 3: Simulating Fission

Simulation: *Simulation 2, Set 1*

- *Select cesium-137 as the element to use in the simulation.*
- *Create an initial sketch of cesium-137. Record observations and the mass number. Make sure to include a key.*
- *Using the simulation, shoot a high-speed neutron at the nucleus of cesium-137.*
- *Pause the simulation immediately after the nucleus is split. Create a sketch of the two smaller nuclei that were created. Record observations and the the atomic mass number of each of the new nuclei.*
- *Reset the simulation for a second trial.*
- *For trial 2, you do not need to create an initial and final sketch. Shoot the neutron at the nucleus. Pause the simulation immediately after the nucleus is split.*
- *Create a sketch of the two smaller nuclei that were created. Record observations and the the atomic mass number of each of the new nuclei.*

	Create a subatomic sketch	Record Data from Monitors			
Initial		Mass Number		Protons	
		Neutrons			
		Record Your Observations			

Trial 1	**Create a subatomic sketch**	**Record Data from Monitors**				
		Element 1	Mass Number		Protons	
			Neutrons			
		Element 2	Mass Number		Protons	
			Neutrons			
		Record Your Observations				
Trial 2	**Create a subatomic sketch**	**Record Data from Monitors**				
		Element 1	Mass Number		Protons	
			Neutrons			
		Element 2	Mass Number		Protons	
			Neutrons			
		Record Your Observations				
Key						

10. In Trial 1, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

11. Do the two elements that are formed after fission have more or less chemical potential energy than the original cesium-137? *Support your claim with evidence.*

12. In Trial 2, what two elements were formed after the heavier nucleus underwent fission? *Support your claims with evidence.*

13. Were the same elements made in Trials 1 and 2? How do you know?

14. Recall that matter cannot be created or destroyed as defined by the Law of Conservation of Mass. The sum of the atomic masses of the two elements produced by the fission of the heavier nucleus is always less than the atomic mass of the element. Why?

15. What types of energy occur in a fission reaction when the chemical potential energy from the heavier nucleus is converted into a new form of energy?

16. What type of energy is being utilized to initiate the nuclear reaction?

Lesson Reflection Question

17. Now that you have explored the concept of **nuclear fission**, describe what you think happens inside nuclear fuel rods to create nuclear energy.